

Let's Talk Water – Radioactive Isotopes (really hot science)

By Dr. Mike Strobel

Last week, we discussed stable isotopes, such as the isotopes of hydrogen and oxygen found in natural waters. We use these isotopes to identify where recharge occurs and generally the flow paths for ground water. This week we will discuss unstable (radioactive) isotopes and how we can use these to age-date water.

The idea of radioactivity typically scares people. We conjure up visions of Three Mile Island or Chernobyl, but most radioactivity occurs naturally in the world and has many uses to humans other than energy generation. You may be surprised how much radioactivity is around us everyday, although the energy levels typically are quite small.

First, let's look at what is radioactivity. Last week, we discussed the make-up of atoms and how isotopes result from extra neutrons in the atoms. The number of neutrons in each atom was stable in that it didn't change over time. Radioactivity is a little different in that the number of protons and neutrons in an atom continue to change spontaneously until a stable atom is formed. The change in protons and neutrons results in the emission of alpha and beta particles and gamma rays, all of which give radioactivity its dangerous reputation. The alpha, beta, and gamma emissions are what result in human health issues because, in sufficient quantities, they can cause cell damage in the body.

It should be pointed out that Federal and State agencies monitor and regulate radioactivity in drinking water. There are established levels for uranium, radium, and gross alpha and beta particles below which it is considered safe to consume. These typically are extremely low levels and most locations in the country meet the standards. Radon may be an exception in Nevada, where many ground-water samples show levels exceeding the proposed maximum contaminant level.

An important radioactive isotope for hydrologists is tritium. Tritium is hydrogen with two neutrons (remember deuterium is hydrogen with one neutron). Tritium in low concentrations occurs naturally and is formed by cosmic rays interacting with atoms in the upper atmosphere.

However, nuclear weapons testing in the 1950s and 1960s added much tritium to the atmosphere. We know when the big increases in tritium occurred because it relates to periods of increased testing. Because of this, if we test for tritium in ground water, we can relate tritium levels to dates of precipitation, and therefore we can estimate when the water was recharged (the age of the water). This works for water that entered the ground after 1953.

Because tritium is radioactive, its concentration is constantly changing and decreases in concentration by half every 12.4 years (this is known as the radioactive half-life for tritium). Above-ground nuclear weapons testing ceased decades ago and tritium levels are

now approaching natural background levels, so we won't be able to use tritium to age date water for much longer.

Another important isotope is carbon-14. Carbon-14 occurs naturally in carbon dioxide. The carbon-14 in the atmosphere is taken up by plants and animals, as well as deposited in some rocks as they form. Once the carbon-14 is isolated from the atmosphere, it begins to decay into carbon-12 (the typical atom of carbon). The half-life of carbon-14 is 5,570 years. Therefore, by looking at the ratio of carbon-14 to carbon-12 in a buried plant or animal remains, we can estimate the date of death, or in rocks, the date of formation. This is a common practice for dating wood and animal remains from the last ice age.

This also works for water. When ground water is recharged, it contains levels of carbon dioxide. By looking at the ratio of carbon-14 to the resultant carbon-12, we can estimate the age of the recharge. Ground water has been dated using carbon-14 to dates of 50,000 to 80,000 years before present. This kind of information is important in determining how long ago water was recharged into an aquifer and the rate of flow within an aquifer.

There are other types of radioisotopes that are used by hydrologists. Chlorine-36 has a half-life of 300,000 years, so it can be used to date very old water. Tritium and iodine-129, as well as other isotopes, are used to identify and track contamination of ground water by nuclear waste.

Therefore, because we know the rate of decay in radioactive isotopes, we can use this as a tool to age-date ground water. However, this provides only part of the story. In addition to determining ages, we also need to use aquifer tests, models, and other tools for obtaining an overall conceptual picture of the hydrology for a region. Stable and radioactive isotopes provide an important part of this process.

In Nevada, questions about Yucca Mountain usually are raised during discussions concerning radioactivity. Numerous agencies, including the USGS, are investigating how water moves through aquifers in the region and how this potentially relates to the suitability of Yucca Mountain as a waste repository. The topic of Yucca Mountain is complex and I would prefer to address it as a specific issue in a future edition of this column.

If you have any questions concerning isotopes, please address them to me at the Ely Times or email me at mstrob@usgs.gov. Next week, we will discuss how to make a stream discharge measurement.